

CONSERVATION DESIGN TOOLS FOR STORMWATER MANAGEMENT

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Abstract

The release of Delaware's "*Conservation Design for Stormwater Management*" document in 1997 provided guidance to land use planners and civil site design consultants in the application of conservation design principles to meet regulatory stormwater management requirements. Proof of concept in this document relied on traditional techniques based on NRCS methodology, such as "*Technical Release No. 55*", to verify the results. However, this was a cumbersome approach, since these methods do not easily model Best Management Practices (BMPs) such as biofiltration swales, bioretention practices and riparian buffers. It became apparent that new tools would have to be developed to model these practices so that prospective developers were given full credit for their implementation. As a result, the Delaware Department of Natural Resources and Environmental Control (DNREC) with assistance from outside contractors, have developed two design tools for use with this so-called "Green Technology" approach to stormwater management. The Delaware Urban Run-off Management Model (DURMM) accounts for both disconnection of impervious area as well as the "run-on" process to derive both the volume and rate of run-off from a given site. A decision tool is also being developed based on USDA's Riparian Ecosystem Management Model (REMM) for designing riparian buffers in an urban environment for both quantity and quality control of stormwater runoff. This decision tool is still under development. Therefore, this paper will focus on the development of DURMM and how it will be used to fulfill the Delaware regulatory requirements for stormwater management. It is also felt that both these tools have application outside the State of Delaware, with the caveat that the local regulatory authority conducts proper testing and verification.

Background

The State of Delaware has had a Sediment & Stormwater Law in effect since 1990. While the law and subsequent regulations were instrumental in mitigating many of the negative impacts associated with urbanization, it soon became clear that traditional approaches were leading to an over dependence on structural practices. If this trend were to continue, the operation and maintenance requirements for these structural practices would become a tremendous burden for the entities responsible for them. In 1996, the Delaware Department of Natural Resources and Environmental Control partnered with the Brandywine Conservancy to develop a manual for a new approach to stormwater management. The goal would be to mimic the natural hydrology of a site as much as possible without relying on structural practices. This new approach to stormwater management was referred to as "Conservation Design".

The "Conservation Design for Stormwater Management" document was released in September, 1997. It provided background information on the hydrologic impacts associated with urbanization and explains how making better use of the existing physical features of a site can minimize the increases in stormwater runoff that often accompanies land development. This can be accomplished by altering the building program, minimizing impervious surfaces and

disconnecting those impervious surfaces wherever possible. Where additional management is required to meet regulatory requirements, the emphasis is on non-structural measures, or “Green Technology BMPs”, such as vegetated swales, biofiltration practices, terraforming, riparian buffers, etc.

Proof of concept for the Conservation Design approach was provided through six case studies of actual development projects throughout the State. The traditional development plans were conceptually redesigned utilizing the Conservation Design principles, while maintaining the original density and unit counts. Stormwater management computations were also completed to ensure full compliance with the existing regulations. These computations were based on traditional NRCS methodology. Although the results confirmed the benefits, it proved to be a rather tedious process. It was clear that an improved methodology would be necessary to take full advantage of this approach. With the assistance of several outside contractors, the DNREC has developed two design tools, the Delaware Urban Runoff Management Model (DURMM) and the Urban Riparian Buffer Design Decision Tool, that will hopefully fill this need.

Delaware Urban Runoff Management Model (DURMM)

Traditional structural BMPs such as stormwater ponds and wetlands can be effective in controlling peak flows from a site. However, current regulatory requirements in the State of Delaware do not address the frequent storms that erode stream banks, and do little or nothing to promote recharge. Furthermore, structural BMPs can contribute to downstream flooding when discharges from separate on-site structural BMPs overlap. Structural BMPs can be effective in pollutant removal; but since they generally omit recharge, consume space, and require extensive maintenance, they are less appropriate for the task. There is an emerging body of research indicating that these BMPs contribute to elevated stream temperatures, and discharge algae laden effluent, which can substantially degrade the benthic community in the receiving stream [Delaware Department of Natural Resources and Environmental Control and B. Lucas, 2002].

As a result, many progressive agencies are promoting a less structural approach, designed to intercept runoff from rooftops, parking lots and roads as close as possible to its source, and direct it into recharge/filtration facilities incorporated into the overall site design and runoff conveyance system. Nonstructural BMPs thus include impervious area disconnection, conveyance of runoff through swales and biofiltration swales, filter strips, terraces, bioretention facilities, and infiltration facilities. However, while these BMPs may seem less significant than structural BMPs, the procedures for their proper design require the same hydrologic and hydraulic methods used in designing structural BMPs. Otherwise, realistic estimates of effectiveness are difficult to quantify. These so-called “Green Technology BMPs”, form the basis of DURMM at the site engineering level.

The BMPs addressed in DURMM and pertinent aspects of their design and performance are briefly summarized below:

Source Area Disconnection- Disconnecting flow from impervious surfaces so it discharges onto adjacent pervious areas provides additional infiltration and potential for some pollutant removal.

Filter Strips- This BMP provides for runoff to be spread uniformly over a filtering surface of vegetation, which can provide substantial treatment if not overloaded by sediment and runoff.

BioFiltration Swales/Grassed Swales- Research shows that overland conveyance through properly designed swales can be very effective in removing Total Suspended Solids (TSS) and adsorbed metals, although less effective in terms of nutrients. While swales are not thought to be capable of quantity management, designs incorporating check dams can provide substantial attenuation of peak flows.

Terraces- Terraces are essentially swales extending across slopes to intercept runoff and increase the potential for infiltration. Terraces are similar to swales in terms of runoff responses and pollutant removal with the exception that flow exfiltrates laterally.

Bioretention Structures- These landscaped pocket depressions incorporated into the urban landscape can provide substantial filtering and nutrient transformations before runoff is discharged into the conveyance system. Ongoing research suggests that this BMP can be designed to have substantial nitrogen removal capabilities, unlike most other BMPs. [Delaware Department of Natural Resources and Environmental Control and B. Lucas, 2002].

Infiltration Practices- Most non-structural BMPs incorporate infiltration as part of the treatment process. Specific infiltration facilities include trenches, basins and dry wells. Infiltration trenches located in swales provide additional wetted surface area and storage volume, and often they can be designed to penetrate shallow impermeable soil profiles to recharge deeper soil horizons.

Unfortunately, while there is great interest in using nonstructural BMPs, there are few rigorous procedures available for the engineering and regulatory community to utilize in designing them. Many regulatory programs use a straightforward runoff volume approach, in which the increase in small storm runoff volume due to land development is to be treated and/or retained on site. However, this approach typically assumes a constant runoff volume in proportion to rainfall amount, and does not route runoff through nonstructural BMPs. Instead, simplified volume/outflow equations are specified, without knowing precisely how they work during storm events. When this approach leads to overdesign, it may be beneficial if the original reduction targets are inadequate, otherwise it causes unnecessary expense. Where it leads to underdesign, the hydrological impacts are not adequately mitigated.

DNREC has partnered with a private consultant, Mr. William Lucas of Integrated Land Management, Inc., to create DURMM to provide a more rigorous hydrological design tool for nonstructural BMPs. A spreadsheet program is provided that incorporates modified TR-20 storm hydrology to project the hydrological response from contributing source areas. It segregates directly connected runoff from that which flows overland. It provides routines that account for the reductions in peak flow due to overland conveyance. In this way, it is possible to more precisely determine the actual volume and peak rate reductions over the duration of a 24 hour storm event, and through the following days. This is particularly important for calculating total infiltration, and designing proper stream bank erosion controls. Furthermore, since the design community is already familiar with TR-20 input variables, the same input data parameters required for design of flood controls can be used for design of quality treatment, streambank protection, and conveyance runoff events.

The process of BMP design involves a spreadsheet file for each source subarea and its BMP. Discrete combinations of hydrological soil group and land cover are averaged to generate composite Curve Numbers (CN)

for the pervious and impervious portions of each source area. Impervious areas are calculated separately, and routed according to the extent of their linkage with adjacent pervious surfaces. The resulting runoff hydrograph from the source area worksheet is imported into the BMP hydraulic design worksheet. Pollutant loading is calculated by applying typical event mean concentrations (EMCs) to the runoff volume allocated to each type of pervious and impervious surfaces.

Site design parameters of infiltration rates, surface and subsurface stage/storage, and outflow controls are entered into the BMP worksheet. The worksheet routes the source area hydrograph through the BMP based upon the input parameters. The resulting output displays peak flows, flow duration and infiltration volume for each storm event.

By segregating subarea loads according to the type and extent of land cover, the discrete source area approach used in the hydrologic calculations refines accuracy in estimating total pollutant loads. Pollutant removal by the BMP is based upon physical parameters such as slope, pretreatment volume, hydraulic residence time, surface/volume ratio, filter media type, and underlying infiltration characteristics. Given these factors, pollutant load reduction is calculated by algorithms relating input concentrations and decay transformations to estimated mass removal for each pollutant of concern.

The reported pollutant removal effectiveness of BMPs can be highly variable. However, by incorporating hydrologic and hydraulic parameters in runoff routing, and addressing the various removal processes as discrete algorithms within a BMP, more accurate estimates of removal rates are possible. Some variability in projected removal rates is acceptable in any event, since hydrological changes are recognized as perhaps the primary impact of runoff. Furthermore, polluted runoff from the most frequent storms that causes the greatest stress can often be eliminated by the infiltration components of nonstructural BMPs.

Conclusions

The Delaware Urban Runoff Management Model (DURMM) was developed to facilitate the adoption of so-called “Green Technology BMPs” in the land development process. This tool is based on rigorous, physically-based methodologies. Yet at the same time, it has advantages in ease of use over the traditional models now being used for stormwater management analysis. It is hoped that the additional development of the riparian buffer decision tool based on the REMM will provide designers with two powerful, quantitative tools that will further encourage the use of Conservation Design techniques.

The DNREC is currently embarking on an extensive outreach and education effort with the design community to introduce this tool and familiarize them with its mechanics. It is anticipated that this effort will allow designers to become proficient with its use within a year’s time.

References

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